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Survey on PAPR Reduction Techniques in OFDM System

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ABSTRACT

Orthogonal frequency division multiplexing (OFDM) is perhaps the most spectrally efficient, robust transmission technique discovered so far for communication systems, and it also mitigates the problem of multipath environment. Due to its advantages in multipath fading channel e.g. robust against ISI, ICI and some other advantages like best QoS for multiple users, efficient usage of bandwidth it is suggested to be the modulation technique for next generation 4G networks e.g. LTE. But along with all its advantages there are some disadvantages also e.g. High PAPR (Peak to Average Power Ratio) at the transmitter end and BER (Bit Error Rate) at the receiving end. OFDM is used in the downlink of 4G networks. To reduce the problems of OFDM some techniques e.g. SLM, PTS, Clipping, Coding, & Pre-coding etc are suggested but none of them is reduce the PAPR and BER to an acceptable value. This Paper will discuss some techniques of PAPR & BER reduction, and their advantages and disadvantages in detail.

KEYWORDS: *PAPR, BER, OFDM, PAPR reduction techniques*

1. INTRODUCTION

Orthogonal Frequency Division Multiplexing is a frequency – division multiplexing (FDM) scheme utilized as a digital multi – carrier modulation method. A large number of closely spaced orthogonal sub – carriers is used to carry data.

The data is divided into several parallel streams of channels, one for each sub – carriers. Each sub – carrier is modulated with a conventional modulation scheme (such as QPSK) rates similar to the conventional single carrier modulation schemes in the same bandwidth. Orthogonal Frequency Division Multiplexing (OFDM) is a Multi-Carrier Modulation technique in which a single high rate data-stream is divided into multiple low rate data-streams and is modulated using sub-carriers which are orthogonal to each other. OFDM is a "Multi-Carrier Transmission Scheme." ODFM is a good solution for high speed digital communications. In this the data to be transmitted is spreaded over a large number of orthogonal Carriers, each being modulated at a low rate. The carriers can be made orthogonal by appropriately choosing the frequency spacing between them. Orthogonal frequency Division multiplexing (OFDM) is a widely used modulation and multiplexing technology, which has become the basis of many telecommunications fields. Therefore OFDM is an advanced modulation technique which is suitable for high-speed data transmission due to its advantages in dealing with the multipath propagation problem, high data rate and bandwidth efficiency.

1. High Spectral Efficiency
2. Robustness to channel fading
3. Immunity to impulse interferences
4. Flexibility
5. Easy equalization

But inspire of these benefits there are some disadvantages in using OFDM:

1. OFDM signal exhibits very high Peak to Average Power Ratio (PAPR)
2. Very sensitive to frequency errors (Tx. & Rx. offset)
3. Intercarrier Interference (ICI) between the subcarriers

OFDM have got certain disadvantages also. One of the major disadvantages of OFDM is high PAPR associated with the transmitted signal. Large PAPR leads to both in-band distortion and out of band radiation. It also increases the complexity of the analog-to-digital and digital-to analog converter and reduces the efficiency of the Radio- Frequency (RF) power amplifier used. Therefore it is useful to reduce the PAPR of the OFDM system. In this paper we are studying different techniques to reduce PAPR in ofdm system

DEVELOPMENT OF OFDM SYSTEMS

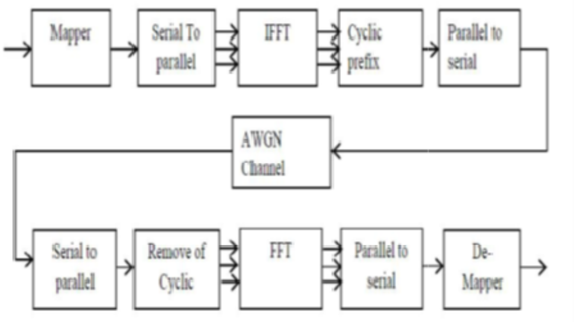
The development of OFDM systems can be divided into three parts. This comprises of Frequency Division Multiplexing, Multicarrier Communication and Orthogonal Frequency Division Multiplexing.

Frequency Division Multiplexing

Frequency Division Multiplexing is a form of signal multiplexing which involves assigning non – overlapping frequency ranges or channels to different signals or to each „user" of a medium. A gap or guard band is left between each of these channels to ensure the signal of one channel does not overlap with the signal from an adjacent one. Due to lack of digital filters it was difficult to filter closely packed adjacent channels.

Multicarrier Communication

As it is ineffective to transfer a high rate data stream through a channel, the signal is split to give a number of signals over that frequency range. Each of these signals are individually modulated and transmitted over the channel. At the receiver end, these signals are fed to a de – multiplexer where it is demodulated and re – combined to obtain the original signal.



Simple block diagram of OFDM system

OFDM THEORY

Orthogonal Frequency Division Multiplexing is a special form of multicarrier modulation which is particularly suited for transmission over a dispersive channel. Here the different carriers are orthogonal to each other, that is, they are totally independent of one another. This is achieved by placing the carrier exactly at the nulls in the modulation spectra of each other.

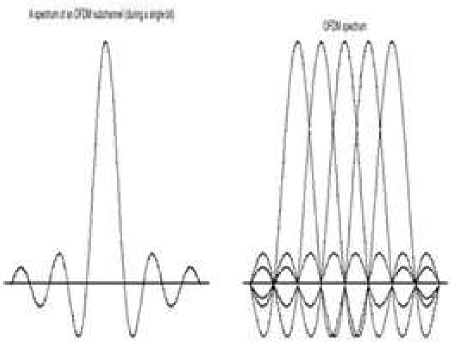


Fig OFDM Spectrum

Orthogonality

Two periodic signals are orthogonal when the integral of their product over one period is equal to zero.

For the case of continuous time:

$$\int_0^T \cos(2\pi n f_0 t)\cos(2\pi m f_0 t)dt = 0,$$

For the case of discrete time:

$$\sum_{k=0}^{N-1} \cos\left(\frac{2\pi kn}{N}\right)\cos\left(\frac{2\pi km}{N}\right)dt = 0,$$

Where $m \neq n$ in both cases

Factors affecting OFDM performance

Bit Error Rate (BER)

In digital transmission, the number of bit errors is the number of received bits of a data stream over a communication channel that has been changed by interference, noise, bit synchronization errors and distortion. The bit error rate (BER) is the number of bits errors divided by the total number of transferred bits. The bit error probability pie is the expectation value of the BER. In communication system, the receiver side BER may be affected by transmission channel distortion, noise, bit synchronization problem, interference, attenuation, and wireless multipath fading. The BER is improved by selecting strong signal strength, by selecting robust and slow modulation scheme or line coding techniques and by applying channel coding techniques such as redundant forward error correction codes.

Inter-carrier Interference (ICI)

The presence of Doppler shifts and frequency, phase offsets in an OFDM system causes loss in orthogonality of the sub carriers. As a result the interference is observed in the sub carriers. It is known as inter carrier interference (ICI) (Arundash and Gagri, 2006-2010). To increase the data rate in OFDM system, the number of OFDM symbol should be increased. As the number of sub carrier increase the frequency spacing between the subcarriers in the OFDM symbol reduces. This makes the OFDM system more sensitive to inter-carrier interference.

Inter – Symbol Interference

Inter – symbol interference (ISI) is a form of distortion of a signal in which one symbol interferes with subsequent symbols. This is an unwanted phenomenon as the previous symbols have similar effect as noise, thus making the communication less reliable. ISI is usually caused by multipath propagation or the inherent non – linear frequency response of a channel causing successive symbols to blur together. The presence of ISI in the system introduces error in the decision device at the receiver output. Therefore, in the design of the transmitting and receiving filters, the objective is to minimize the effects of ISI and thereby deliver the digital data to its destination with the smallest error rate possible.

PAPR

PAPR occurs when in a multi-carrier system the different sub-carriers are out of phase with each other. At each instant they are different with respect to each other at different phase values. When all the points achieve the maximum value simultaneously; this will cause the output envelope to suddenly shoot up which causes a 'peak' in the output envelope. Due to presence of large number of independently modulated sub-carriers in an OFDM system, the peak value of the system can be very high as compared to the average of the whole system. This ratio of the peak to average power value is termed as Peak-to-Average Power Ratio. An OFDM signal consists of a number of independently modulated sub-carriers which can give a large PAPR when added up coherently. When N signals are added with the same phase they produce a peak power that is N times the average power of the signal. So OFDM signal has a very large PAPR, which is very sensitive to non-linearity of the high power amplifier. In OFDM, a block of N symbols{X , k = 0,1,....,N -1} k , is formed with each symbol modulating one of a set of subcarriers, {f , k = 0,1,.....,N -1} k . The N subcarriers are chosen to be orthogonal, that is, f k f k = D , where Df =1 NT and T is the original time period. The resulting signal is given as:

$$x(t) = \sum_{n=0}^{N-1} X_k e^{j2\pi f_k t} \quad ,$$

$$0 \leq t \leq NT$$

PAPR is defined as:

$$PAPR = \frac{\max|x(t)|^2}{E\left[|x(t)|^2\right]}$$

Where E [.] denotes the expectation operator.

PAPR Problem

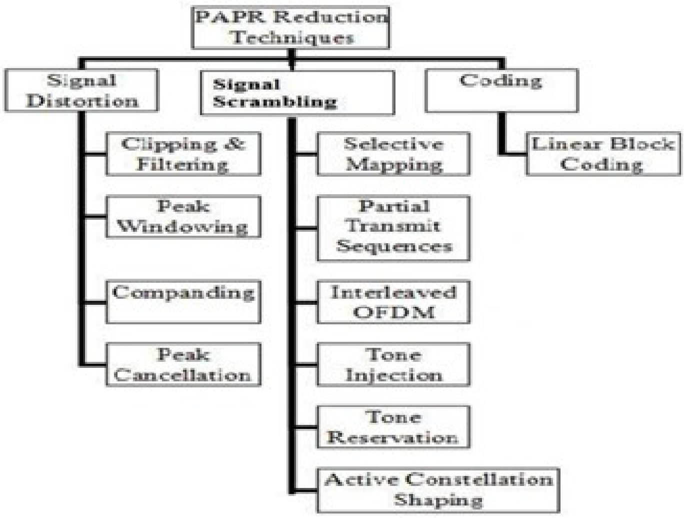
One of the new problems emerging in OFDM systems is the so-called Peak to Average Power Ratio (PAPR) problem. The input symbol stream of the IFFT should possess a uniform power spectrum, but the output of the IFFT may result in a non-uniform or spiky power spectrum. Most of transmission energy would be allocated for a few instead of the majority subcarriers. This problem can be quantified as the PAPR measure. It causes many problems in the OFDM system at the transmitting end.

Effect of PAPR

There are some obstacles in using OFDM in transmission system in contrast to its advantages:

1. A major obstacle is that the OFDM signal exhibits a very high Peak to Average Power Ratio (PAPR).
2. Therefore, RF power amplifiers should be operated in a very large linear region. Otherwise, the signal peaks get into non-linear region of the power amplifier causing signal distortion. This signal distortion introduces inter-modulation among the subcarriers and out of band radiation. Thus, the power amplifiers should be operated with large power back-offs. On the other hand, this leads to very inefficient amplification and expensive Transmitters. Thus, it is highly desirable to reduce the PAPR.

PAPR Reduction Techniques



1. Clipping & Filtering

A threshold value of the amplitude is set in this process and any sub-carrier having amplitude more than that value is clipped or that sub-carrier is filtered to bring out a lower PAPR value.

2. Peak Windowing:

Peak windowing reduces PAPRs at the cost of increasing the BER and out-of-band radiation. In peak windowing method we multiply large signal peak with a specific window, for example; Gaussian shaped window, cosine, Kaiser and Hamming window.

Signal Scrambling Techniques

1. Selected Mapping

In this a set of different data blocks representing the information same as the original data blocks are selected. Selection of data blocks with low PAPR value makes it suitable for transmission.

2. Partial Transmit Sequence

Transmitting only part of data of varying sub-carrier which covers all the information to be sent in the signal as a whole is called Partial Transmit Sequence Technique.

3. Interleaving

The notion that highly correlated data structures have large PAPR can be reduced, if long correlation pattern is broken down. The basic idea in adaptive interleaving is to set up an initial terminating threshold. PAPR value goes below the threshold rather than seeking each interleaved sequences.

4. Tone Reservation (TR)

The main idea of this method is to keep a small set of tones for PAPR reduction. This can be originated as a convex problem and this problem can be solved accurately.. Tone reservation method is based on adding a data block and time Domain signal. A data block is dependent time domain signal to the original multicarrier signal to minimize the high peak.

5. Tone Injection (TI)

It is based on additive method for PAPR reduction. Using an additive method achieves PAPR reduction of multicarrier signal without any data rate loss. It uses a set of equivalent constellation points for an original constellation points to reduce PAPR

Coding

1. Block Coding

The fundamental idea is that of all probable message symbols, only those which have law peak power will be chosen by coding as valid code words for transmission.

2. Pre-coding

In pre-coding method, modulated data is multiplied with shaping matrix before the formation of OFDM symbol. This type of technique utilizes the positive feature of the frequency selective multipath channel of OFDM system. In this first the input data is modulated in baseband using modulation scheme like M-PSK, M-QAM etc. The baseband-modulated data stream is transformed by pre-coding matrix. Different methods like pulse shaping function, discrete cosine transformation (DCT) matrix, Hadamard matrix, zadoff-chu sequence, generalized chriplike (GCL) sequence etc. are used to generate pre-coding matrix. After that these pre-coded data are transmitted through IFFT and generate OFDM symbols. Each element of precoding matrix should be carefully designed, so that it can reduce the PAPR. Since, we are multiplying modulated data with predefined pre-coding matrix, there is no need of handshake between transmitter and receiver.

COMBINATION OF SCRAMBLING AND PRECODING TECHNIQUES:

This paper pre-coder will be combined with scrambling technique and the system performance will be compared. SLM, PTS, DCT can provide good performance for PAPR reduction, and this improvement requires a high computational complexity. Several techniques have been proposed based on low-complexity SLM techniques. SLM requires the transmission of several side information bits for each data block. These bits must generally be channel-encoded because they are particularly sensitive to the error performance of the system. This increases the system complexity and transmission delay, and decreases the data rate.

In this article, a VLM precoded SLM and combination of DCT with SLM and HADAMARD with SLM techniques has been proposed to reduce the PAPR in OFDM signals. Combination of pre-coding and scrambling techniques reduce PAPR much more as compare to other techniques.

RELATED WORK

The precoding based PAPR reduction techniques show great promise as they are simple linear techniques to implement without the need of any side information to be sent to the receiver. Few recent works based on precoded OFDM systems are given in [8–14]. Walsh–Hadamard transform (WHT), is a very popular precoding in the literature, but unfortunately the PAPR gain is very less. On the other hand, Discrete-Hartley transform (DHT) precoding is presented and Zadoff-Chu matrix transform (ZCMT) precoding in which are very effective solutions for PAPR problem. But the computational complexity increases in ZCMT than WHT or DHT precoding as it involves some extra stages of multiplication.

Sun et.al [12] presented a DCT precoded PAPR reduction technique for MSE–OFDM system and it is shown that DCT based precoding technique can considerably reduce the PAPR without degrading the error performance. In this we proposed another DCT precoder based SLM technique and HADAMARD precoder based SLM and VLM precoding SLM technique for PAPR reduction with less computational complex than other precoders and it does not require any complex optimization technique.

CCDF OF PAPR

The cumulative distribution function (CDF) is one of the most regularly used parameters, which is used to measure the efficiency of any PAPR Technique. The cumulative distributed function (CDF) of the signal is

$F(z) = 1 - \exp(z)$

The complementary cumulative distributed function (CCDF) is used instead of CDF which helps us to measure the probability that the PAPR of a certain data block exceeds the given threshold.

$P(PAPR > z) = 1 - P(PAPR \leq z) = 1 - F(z)N = 1 - (1 - \exp(-z))N$

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